

FIG. 1

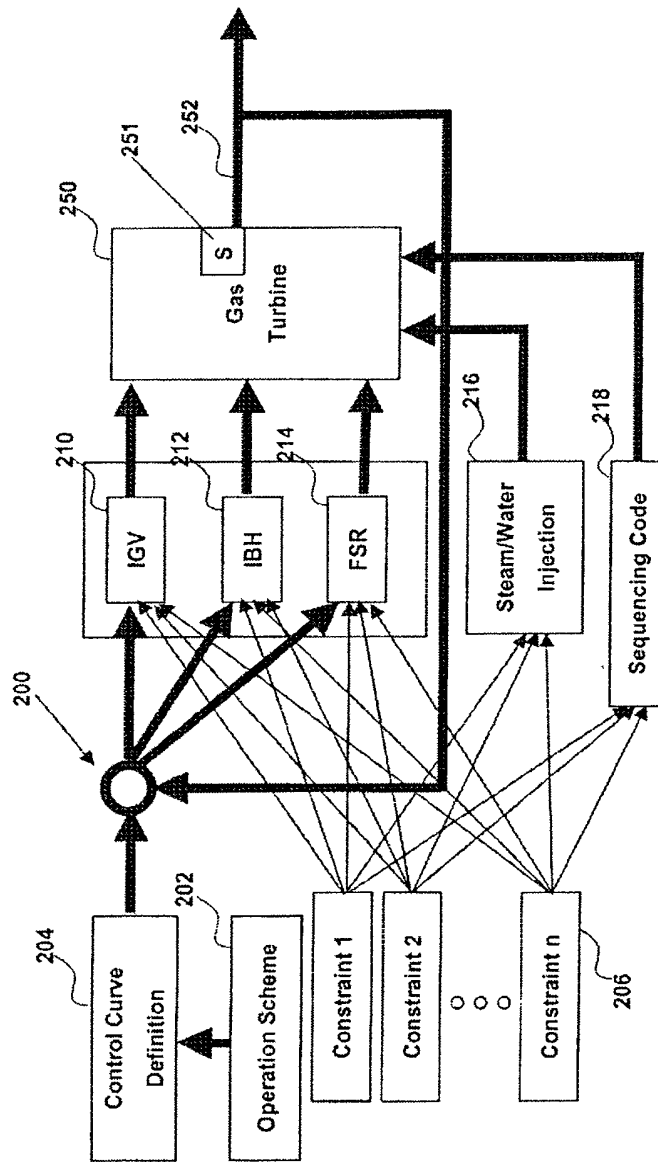


FIG. 2

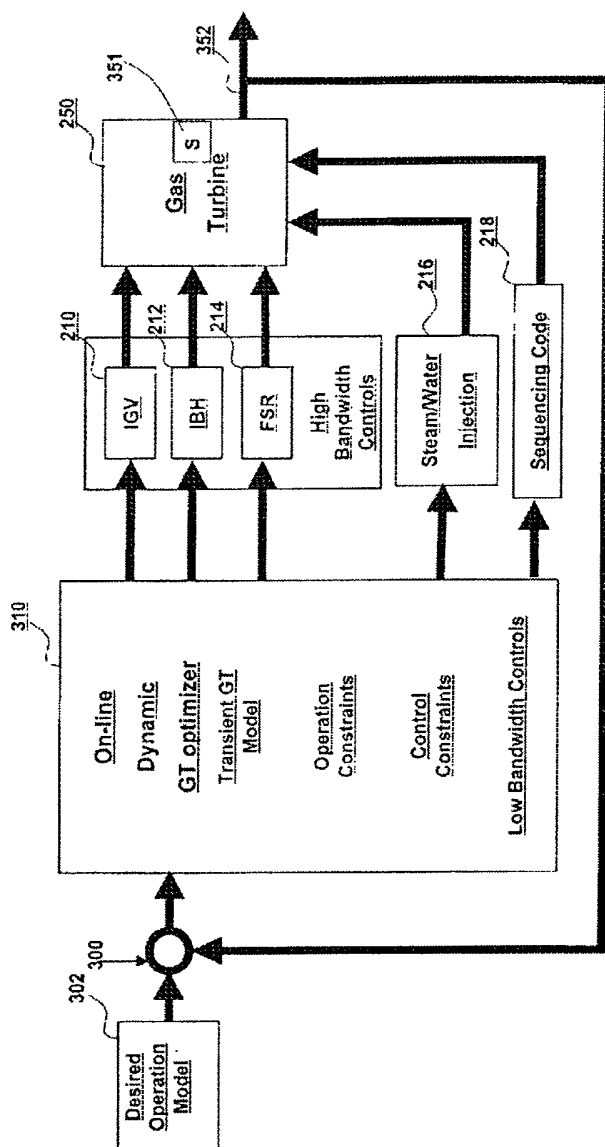


FIG. 3

Compressor Inlet Model

$$\dot{m}_{comp} c_p T_{comp, in} = \dot{m}_{bleed} c_p T_{bleed} + (\dot{m}_{comp} - \dot{m}_{bleed}) c_p T_{amb}$$

$$P_{comp, in} = P_{amb} - \Delta P_{inlet}$$

$$\Delta P_{inlet} = f(\dot{m}_{comp})$$

$$\text{Specific Humidity} = \frac{0.622 * (\text{Relative Humidity})}{\left(\frac{P_{amb}}{P_{dry}} - \text{Relative Humidity} \right)}$$

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Compressor Model

$$\dot{m}_{comp, corrected} = f(X_c, N_c)$$

$$\eta_{comp} = f(X_c, TNH_{cor}, SH)$$

$$\dot{m}_{comp} = \dot{m}_{comp, corrected} \sqrt{\frac{T_{comp, in}}{T_{ISO}}} \frac{P_{comp, in}}{P_{ISO}} + f(SH)$$

$$T_{comp, exit} = \frac{T_{comp, in}}{\eta_{comp}} \left[(X_c)^{\frac{\gamma-1}{\gamma}} - 1 \right] + T_{comp, in}$$

$$\dot{m}_{9th, stage} = f(X_c, N_c, IGV)$$

$$\dot{m}_{13th, stage} = f(X_c, N_c, IGV)$$

$$\dot{m}_{17th, stage} = f(X_c, N_c, IGV)$$

$$\dot{m}_{18th, stage} = f(X_c, N_c, IGV)$$

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FIG. 5A

Compressor Model Continued

$$\dot{m}_{nonchargeable} = \frac{C_d A P_{comp,exit}}{\sqrt{RT_{comp,exit}}} \left(\gamma^{1/2} \left(\frac{2}{\gamma+1} \right)^{\frac{\gamma+1}{\gamma-1}} \right)$$

$$\dot{m}_{discharge\ volume} = \dot{m}_{comp} - \dot{m}_{9th,sg} - \dot{m}_{13th,sg} - \dot{m}_{17th,sg} - \dot{m}_{18th,sg} - \dot{m}_{nonchargeable}$$

$$\dot{P}_{comp,exit} = \frac{\dot{m}_{discharge\ volume} R T_{comp,exit}}{V_{discharge}}$$

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Since bleed flows are from the compressor to the turbine via some piping, a small lag is introduced in the flows to account for this:

$$\frac{d\dot{m}_{ith,sg\ bleed\ to\ turbine}}{dt} = \frac{\dot{m}_{ith,sg\ bleed\ from\ compressor} - \dot{m}_{ith\ sg\ bleed\ to\ turbine}}{\tau_{comp}}$$

Compressor Heat Soak Model

$$\frac{dT_{metal}}{dt} = \frac{Q}{m_{metal} c_{p,metal}}$$

$$Q = h(T_{comp,avg} - T_{metal})$$

$$T_{comp,avg} = \frac{T_{comp,exit} + T_{9th,sg}}{2}$$

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FIG. 5B

Compressor Model Continued

Compressor HP Calculation

$$\begin{aligned} \text{CompressorHP} = & \dot{m}_{comp} c_p T_{comp,in} - \dot{m}_{9thsig} c_p T_{9thsig} - \dot{m}_{13thsig} c_p T_{13thsig} - \\ & \dot{m}_{17thsig} c_p T_{17thsig} - \dot{m}_{18thsig} c_p T_{18thsig} - \\ & (\dot{m}_{comp} - \dot{m}_{9thsig} - \dot{m}_{13thsig} - \dot{m}_{17thsig} - \dot{m}_{18thsig}) c_p T_{comp,exit} \end{aligned}$$

Combustor Model

$$T_{flame} = f(\dot{m}_{fuel}, \dot{m}_{comb}, T_{air,comb}, T_{fuel}, SH, P_{comp,exit})$$

$$\Delta P_{comb} = f(P_{comp,exit}, T_{comp,exit}, T_{flame}, SH)$$

Combustor dynamics modeled with a lag for flame temperature and turbine inlet pressure:

$$\begin{aligned} \frac{dT_{flame,out}}{dt} &= \frac{T_{flame,in} - T_{flame,out}}{\tau_{comb}} \\ \frac{dP_{turbine,in}}{dt} &= \frac{(P_{comp,exit} - \Delta P_{comb}) - P_{turbine,in}}{\tau_{comb}} \end{aligned}$$

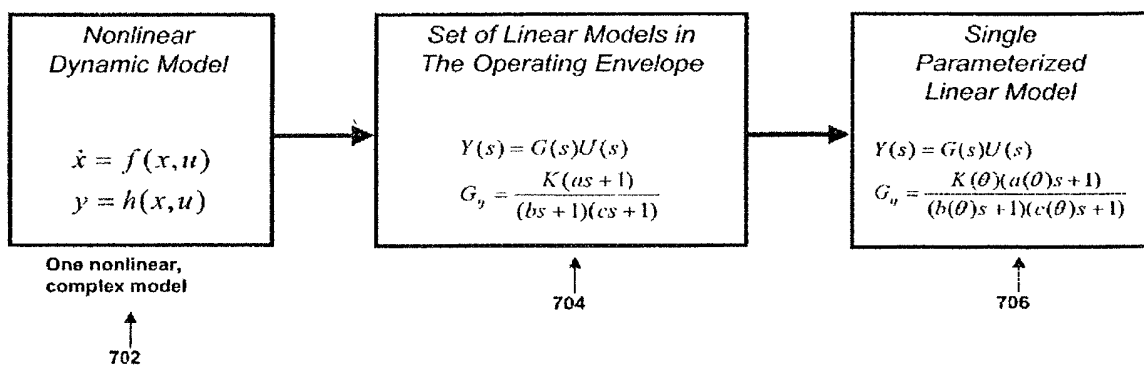
FIG. 5C

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\dot{m}_{comp}	Total mass flow from compressor
$T_{comp,in}$	Temperature of air entering compressor
\dot{m}_{bleed}	Mass flow of inlet bleed air
T_{amb}	Ambient temperature
$P_{comp,in}$	Inlet pressure to compressor
ΔP_{inlet}	Inlet pressure drop
P_{amb}	Ambient pressure
P_{dry}	Dry vapor pressure
$\dot{m}_{comp,corrected}$	Corrected mass flow from compressor
X_c	Pressure ratio across compressor
N_c	Corrected speed
$T_{NH_{cor}}$	Corrected speed
η_{comp}	Compressor efficiency
c_p	Specific heat at constant pressure
$T_{comp,out}$	Compressor discharge temperature
γ	Ratio of specific heats
IGV	Inlet guide vane angle
P_{ISO}	Pressure at ISO conditions
T_{ISO}	Temperature at ISO conditions
$\dot{m}_{non,chargeable}$	Mass flow from compressor directly to turbine inlet
R	Gas constant
$C_d A$	Effective area
$\dot{m}_{discharge,volume}$	Mass flow in the compressor discharge plenum
$V_{discharge}$	Volume of compressor discharge plenum
τ_{comp}	Compressor time constant
Q	Heat flux
h	Heat transfer coefficient
m_{metal}	Compressor mass
$C_{p,metal}$	Heat capacity of compressor
CompressorHP	Horsepower absorbed by compressor
T_{flame}	Flame temperature
ΔP_{comb}	Combustor pressure drop
τ_{comb}	Combustor time constant
$P_{turbine,in}$	Turbine inlet pressure

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Fig. 6



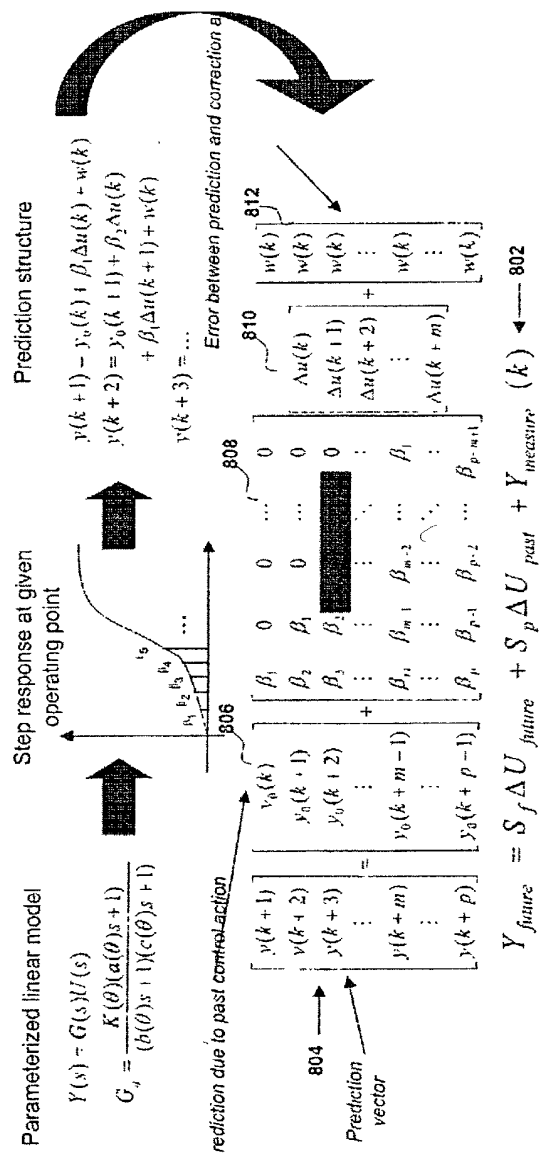


FIG. 8

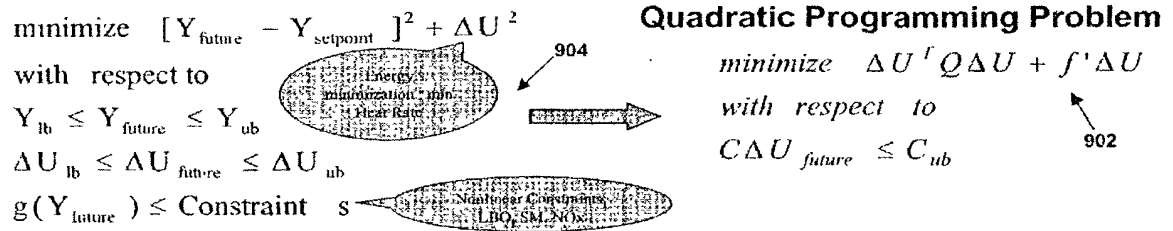


FIG. 9